55. A method according to claim 50 wherein said light fuses a surface of said semiconductor film in the irradiating step.--

REMARKS

The Official Action of October 21, 1997 was received and its contents carefully reviewed. Reconsideration and withdrawal of the currently pending rejections are requested for the reasons advanced in detail below.

A *Petition for a One-Month Extension of Time* is also being filed simultaneously herewith to extend the time period for response to February 21, 1998 (actually, February 23, 1998 in view of the weekend). Consequently, the instant amendment should be considered timely filed.

Claims 1-4, 6-15 and 17-23 were pending prior to this amendment. By this amendment, claims 1-4, 6-15 and 17-23 are cancelled, and new claims 24-55 are added. These new claims are added rather than amending the prior pending claims in view of the numerous §112 rejections in the Official Action. Otherwise, the invention recited in these new claims is similar to that originally filed with additional features included therein to overcome the §112 rejections and to further distinguish the present invention over the cited art of record. Thus, this amendment should be considered responsive to the outstanding Official Action. Claims 24-55 are currently pending in the instant application.

Initially, addressing the formal objections, the Title is objected to for being non-descriptive. The Title is amended herein to overcome this objection.

Claims 1-4, 6-15 and 17-23 are rejected under 35 U.S.C. §112, second paragraph for being indefinite. This rejection is rendered moot by the cancellation of claims 1-4, 6-15 and 17-23.

Applying this rejection to the currently pending claims, the Examiner asserts that "the steps" lacks proper antecedent basis, because these are new

steps. This language is commonly used in method claims, particularly in the preamble to introduce the recited steps of the disclosed method. Furthermore, use of the word "the" before an initial introduction is not a "per se" violation of §112, second paragraph, particularly when dealing with inherent components. (See, M.P.E.P. §2173.05(e)) Certainly, a method should be considered to inherently have "steps" associated therewith. Moreover, the patents cited by the Examiner, such as Takemura, U.S. Patent No. 5,403,762, include "the steps of" in their preambles. Accordingly, this §112 rejection should be reconsidered and withdrawn.

The remaining rejections of the claims under §112, second paragraph, provided on pages 2-3 of the Office Action, are overcome by the cancellation of claims 1-4, 6-15 and 7-23 and are not believed present in claims 24-55.

Claims 1-4 are also rejected under 35 U.S.C. §112, first paragraph, as containing subject matter which is not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventors, at the time the application was filed, had possession of the claimed invention. This rejection is overcome by the cancellation of claims 1-4. Further, new claims 24-55 recite the defect reducing heating step after crystallization.

Claims 6-13 and 17-23 are also rejected under 35 U.S.C. §112, first paragraph, as containing subject matter which is not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventors, at the time the application was filed, had possession of the claimed invention. This rejection is overcome by the cancellation of claims 6-13 and 17-23, and new claims 25, 33, 42 and 51 recite the use of a nitrogen atmosphere in the second heating step.

Claims 6-9, 11-15 and 17-23 are also rejected under 35 U.S.C. §112, first paragraph, because the specification, while being enabling for irradiating an amorphous Si film supplied with a metal catalyst for promoting

crystallization, does not allegedly support use of a laser alone for the initial crystallization. This rejection is similarly overcome by the cancellation of claims 6-9, 11-15 and 17-23, and new claims 24-55 include a first heating step for crystallization and an irradiating step for further crystallization.

The present invention is characterized by heating a crystalline semiconductor film to decrease crystal defects therein, wherein an amorphous silicon film is crystallized by heating and subsequently irradiating with a light using a catalyst material such as nickel. The main feature of this invention is heating the crystalline semiconductor film after the crystallizing step, so that defects in the semiconductor film can be reduced, as more specifically described at page 11, lines 6-10 of the specification.

Another feature recited in claims 24, 32, and 41 is applying a solution including a catalyst material capable of promoting crystallization of the semiconductor film. The solution is useful to control the amount of the catalyst material, indicated at page 7, lines 14-20 of the specification, since too much catalyst material can adversely affect the semiconductive properties of the resulting semiconductor layer.

Still another feature of the present invention is the promotion of crystal growth in a lateral direction, which is included in claims 32 and 41. This specific feature is disclosed at page 13, lines 10-19.

More specific features of the present invention are recited in the remaining claims, namely,

1) Claims 25, 33, 42, and 51 recite that the second heating steps are performed in a nitrogen atmosphere, described at page 12, lines 8-10.

2) Claims 26, 34, 43, and 52 recite the catalyst material, disclosed at page 4, lines 2-3.

3) Claims 27, 35, and 44 include the polar solvents, disclosed at page 9, lines 1-2.

4) Claims 28, 36, and 45 are specified with the non-polar solvents, disclosed at page 9, lines 9-11.

5) Claims 38 and 47 include the concentrations of the catalyst material in the semiconductor film, disclosed at page 21, lines 4-9.

6) Claims 31, 40, 49, and 55 recite that a surface of the semiconductor film is in a fused state, disclosed at page 14, line 26 through page 15, line 5 of the specification.

Claims 1-4 are rejected under 35 U.S.C. §103(a) as being unpatentable over Takemura. This rejection is rendered moot by the cancellation of claims 1-4. Furthermore, the presently claimed invention is distinguishable over this reference.

The present invention has a specific feature of crystallizing an amorphous semiconductor film by heating, further crystallizing the crystallized semiconductor film by irradiating with a light such as a laser light, and then heating the crystallized semiconductor film to reduce the crystal defects, as mentioned above. This feature is claimed in the pending claims 1, 2, 6, 11, 14, 17, 21, and 22, and rejected over Takemura, U.S. Patent 5,403,762.

Takemura discloses that the thermal annealing may be carried out after or before the laser irradiation (column 5, lines 50-51). However, these irradiating and thermal annealing steps of Takemura are performed to activate impurities (column 5, lines 42-44) while the irradiating step of the present invention is for crystallization and the second heating step is for decreasing the crystal defects in the crystallized semiconductor film.

Takemura also indicates, at column 7, lines 11-52 thereof, that the semiconductor film is irradiated with a laser light to recrystallize after implanting impurity ions thereinto. This irradiating step is also carried out to impair the damaged semiconductor film by implanting impurities, which is

entirely different than the instant invention. Takemura also discloses that an amorphous silicon film is formed and irradiated with a laser light to crystallize. The crystallized silicon film is irradiated with an infrared light to reduce defects and dangling bonds. Then, the crystallized silicon film is annealed at 350°C for 2 hours in a hydrogen atmosphere (column 8, lines 14-40). Even though Takemura discloses reducing defects and dangling bonds, this patent is distinct from the instant invention for the additional reasons advanced below.

The defects and dangling bonds in the silicon film of Takemura is reduced by irradiating with an infrared light while those of the claimed invention by heating at a temperature of 450-750°C in a nitrogen atmosphere, which is described at page 11 lines 6-10, as mentioned above. Takemura does not indicate the temperature during or by irradiating with the infrared light. After irradiation with infrared light, Takemura's silicon film is thermally annealed at 350°C for 2 hours in a hydrogen atmosphere. The temperature of this annealing step is different from that of the present invention. Furthermore, the atmospheres of Takemura and the claimed invention is also different because the reference teaches hydrogen while the present specification discloses nitrogen. In addition, Takemura does not indicate the purpose of annealing the silicon film.

For the above reasons, new claims 24-55 should be considered patentable over Takemura.

Claims 1-4 are also rejected under the judicially created doctrine of obviousness-type double patenting over claims 1-8 of U.S. Patent No. 5,403,762. This rejection is rendered moot by the cancellation of claims 1-4, and new claims 24-55 recite additional steps not recited in claims 1-8 of the '762 patent.

Claims 1-4 are rejected under 35 U.S.C. §102(e) over Zhang et al. ('937). This rejection is also rendered moot by the cancellation of claims 1-4, and new claims 24-55 recite additional steps not disclosed by Zhang et al.

Specifically, in column 4, lines 1-32, Zhang ('937) discloses that a temperature of 600°C or more can be obtained by irradiating with a strong beam (column 4, lines 16-17). However, Zhang does not teach heating the silicon film other than irradiating with a light.

Also, Zhang's irradiating step to cause this temperature is to promote further crystallization (column 4, line 20). Zhang discloses that the dangling bonds are reduced by thermally annealing in an atmosphere containing hydrogen at a temperature of from 200-450°C (column 4, lines 27-29). The temperature range and atmosphere of the thermal annealing step of Zhang are different from those of the claimed invention.

In column 4, line 59 - column 5, line 20, Zhang teaches that Si film can be heated by irradiating strong light or by heating during oxidation (column 4, lines 65-66). This oxidation step is to form a thermal oxide film on a surface of a crystallized silicon film, and is performed in an oxidizing atmosphere containing a halogen element (column 4, lines 33-41). Further, the silicon film of Zhang is irradiated with a strong light or a laser light to promote further crystallization. This silicon film is heated to 600°C or less and is not to decrease the defects therein but to crystallize (column 5, lines 6-9). During and/or after irradiating, Zhang does not include to heat the silicon film.

In column 5, line 58 - column 6, line 52, Zhang's silicon film is irradiated with a visible light or a near infrared light to promote further crystallization (column 6, lines 36-38). Before the irradiating step, this silicon film is crystallized by heating at a temperature of 400-650°C (column 6, lines 33-35). There is absolutely no description of decreasing defects as in the present invention.

In column 9, lines 15-45 and 46-59, Zhang discloses that an amorphous silicon film is formed and crystallized at 550°C in an inactive atmosphere for 4 to 8 hours (column 9, lines 23-25). The crystallized silicon film is irradiated

with an infrared light or a laser light to promote further crystallization (column 9, lines 47-48). Although irradiating with the infrared light or the laser light causes a temperature of 800-1300°C (column 9, lines 50-52), Zhang does not teach heating at the temperature other than irradiating.

After irradiating to promote further crystallization, another irradiating step in a hydrogen atmosphere is performed to decrease reduce defects or dangling bonds in active layers (column 9, lines 55-59). However, Zhang does not indicate heating the active layers other than by irradiating. Also, Zhang does not teach a temperature of the irradiating step to decrease the defects or the dangling bonds. Further, the atmosphere is hydrogen which is different from nitrogen that the present invention claims.

In column 9, lines 60-67, Zhang teaches heating at a temperature of 300-550°C (column 9, lines 63-65). However, the substrate of Zhang is heated during forming silicon oxide film as a gate insulating film (column 9, lines 60-61). Therefore, the purpose of heating at the temperature is completely different between Zhang and the present invention.

In column 10, lines 20-41, 42-51, the substrate of Zhang is heated at a temperature of 200-450°C (column 10, lines 49-50). This thermal annealing at that temperature is carried out during irradiating with a laser light (column 10, lines 42-43) after ion implantation (column 10, line 23). Even though it is not clearly described, the irradiating step should be performed to active the impurity ions.

Further, in column 11, lines 12-16, the reference teaches that dangling bonds caused in the process of light annealing by visible light or near infrared rays are neutralized by heating them at a temperature of from 250° to 400°C in the atmosphere of hydrogen in a later process. However, the temperature and the atmosphere of the claimed invention are 450-750°C and nitrogen.

Accordingly, Applicants contend that the newly added claims overcome the reference of Zhang.

Claims 1-4 are rejected under 35 U.S.C. §103(a) as being unpatentable over Fan et al. This rejection is also rendered moot by the cancellation of claims 1-4, and new claims 24-55 recite additional steps which Applicants contend are not disclosed by Fan et al.

Claims 6-13 and 17-22 are rejected under 35 U.S.C. §103(a) over Fan et al. or Celler, in view of Hemple et al. or Hayzelden et al. and further in view of Pressley. This rejection is also rendered moot by the cancellation of claims 6-13 and 17-22, and new claims 24-55 recite additional steps which Applicants contend are not disclosed by these references.

Specifically, the feature of adding a solution, which is included in the pending claims 11, 13, 14, 17, and 21, was rejected over U.S. Patent No. 4,415,373 to Pressley. Pressley discloses that a liquid which incorporates a dopant is introduced in contact with a non-active surface (NAS) of a semiconductor such as a single crystal silicon wafer (column 3, lines 3-11; column 2, lines 19-24; and column 2, lines 31-33). An object of introducing a liquid into the semiconductor of Pressley is diffusing the dopant in the liquid into the non-active surface of the silicon wafer.

On the other hand, an object of the instant invention to add a solution to the semiconductor film is introducing a catalyst material for promoting crystallization of the amorphous semiconductor film which enhances the ability to control the amount of catalyst material actually contacting the semiconductor film. Further, Pressley utilizes a silicon wafer while the claimed invention uses an amorphous semiconductor film. Therefore, the objects of Pressley and the present application are clearly different from each other, and, thus, cannot suggest to one of skill in the art to use the method of Pressley for dopants for introducing a crystallization promoting catalyst of the present invention.

Claims 14, 15 and 23 are rejected under 35 U.S.C. §103(a) over Fan et al. or Celler, in view of Hemple et al. or Hayzelden et al., further in view of Pressley, and further in view of Liu et al. or Zhang et al. ('291). This

rejection is rendered moot by the cancellation of claims 14, 15 and 23. Further, the newly added claims should be considered distinguished over these references for the reasons advanced in detail above.

Claims 1-4 are rejected under the judicially created doctrine of obviousness-type double patenting as being unpatentable over claims 1, 2, 8, 11-12, 15, 30-32, 34, 39, 42, 44, and 47-48 of Zhang et al. ('937), further in view of Liu et al. This rejection is rendered moot by the cancellation of claims 1-4 and, the newly added claims should be considered distinguished over these references for the reasons advanced in detail above.

Claims 1-4, 6-15 and 17-23 are rejected under the judicially created doctrine of obviousness-type double patenting as being unpatentable over claims 1-20 of Ohtani et al. ('352), further in view of Liu et al. and Fan et al. This rejection is rendered moot by the cancellation of claims 1-4, 6-15 and 17-23 and, the newly added claims 24-55 should be considered distinguished over these references for the reasons advanced in detail above.

Further, U.S. Patent 5,543,352 to Ohtani et al. teaches using a solution including a catalytic material for promoting crystallization of silicon. However, Ohtani does not indicate heating the crystallized semiconductor film to reduce crystal defects after crystallization. Although Ohtani discloses heating a crystallized silicon film in an oxidizing atmosphere at a temperature of 500-750°C (column 13, lines 29-34), the object of the thermal treatment is not to decrease spin density in the silicon film, as the claimed invention discloses, but to oxidize the silicon film to form an oxide film on the silicon island (column 13, lines 29-31). Consequently, newly pending claims 24-55 should be considered allowable over this reference.

In view of the foregoing, it is respectfully requested that the rejections of record be reconsidered and withdrawn, that new claims 24-55 be allowed and that the application be passed to issue. If a conference would be beneficial

in expediting the prosecution of the instant application, the Examiner is hereby invited to telephone the undersigned to arrange such a conference.

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